EVM User's Guide: LMR51635EVM

LMR51635 Buck Evaluation Module

Description

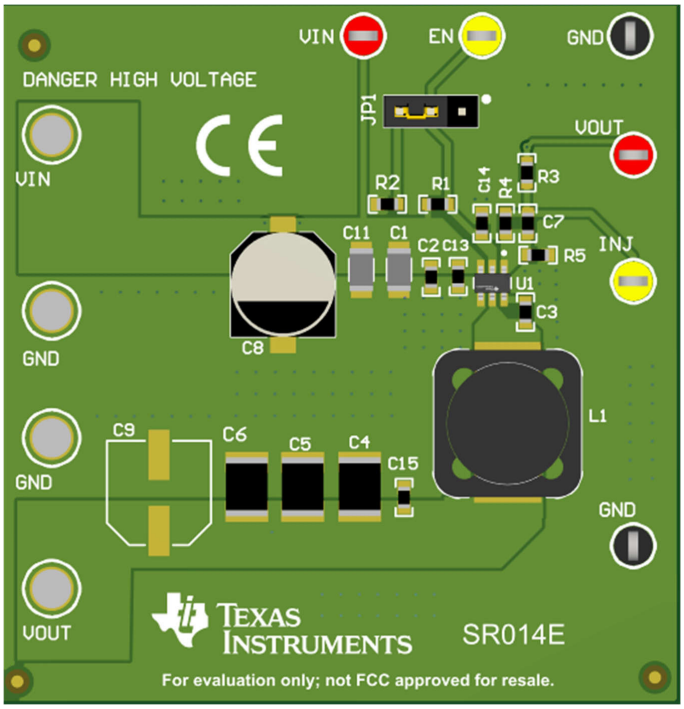
The Texas Instruments LMR51635EVM evaluation module (EVM) helps designers evaluate the operation and performance of the LMR51635 wide-input synchronous buck regulator. The LMR51635 is a wide-V_{IN}, easy-to-use synchronous buck converter. With the wide operating input voltage range of 4.3V to 60V, the device is designed for a wide range of industrial applications for power conditioning from an unregulated source. The LMR51635 operates at 400kHz switching frequency to support use of relatively small inductors for an optimized design size. The LMR51635 supports up to 3.5A continuous output current.

Features

- 4.3V to 60V input voltage range
- Default 5V output
- 3.5A continuous output current capability
- 400kHz switching frequency
- Hiccup mode short-circuit protection
- Frequency spread spectrum

Applications

- Major appliance
- PLC, DCS, and PAC
- Smart meters
- General purposes wide V_{IN} power supplies



LMR51635EVM Top View

1 Evaluation Module Overview

1.1 Introduction

The LMR51635EVM evaluation module (EVM) is a single, synchronous buck converter providing 5V at 3.5A output from 6V to 60V input. Table 1-1 shows the rated input voltage and output current ranges for the evaluation module.

Table 1-1. Input Voltage and Output Current Summary

EVM	Input Voltage (V_{IN}) RANGE	OUTPUT CURRENT (I_{OUT}) RANGE
LMR51635EVM	6V to 60V	0A to 3.5A

This user's guide contains information for the LMR51635 as well as support documentation for the LMR51635EVM evaluation module. This user's guide includes the performance specifications, schematic, and the bill of materials of the LMR51635EVM.

1.2 Specification

A summary of the LMR51635EVM performance specifications is provided in Table 1-2. Specifications are given for an input voltage of V_{IN} = 24V and an output voltage of 5V, unless otherwise noted. The ambient temperature is 25°C for all measurement, unless otherwise noted.

Table 1-2. LMR51635EVM Performance Specifications Summary

SPECIFICATIONS	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage range (V_{IN})		6	24	60	V
Output voltage			5		V
Operating frequency	V_{IN} = 24V, I_{OUT} = 3.5A		400		kHz
Output current range		0		3.5	A
Output ripple voltage	V_{IN} = 24V, I_{OUT} = 3.5A		25		mV_{PP}
Efficiency	V_{IN} = 24V, I_{OUT} = 3.5A		90		%

1.3 Device Information

The purpose of LMR51635EVM is to showcase the typical application of the LMR51635 device.

2 Hardware Setup and Test Resutls

This section describes the jumpers and connectors on the EVM and how to properly connect, set up, and use the LMR51635EVM. The section also includes test results of output voltage ripple and start-up.

2.1 Setup

2.1.1 Input and Output Connector Description

- **V_{IN} — Terminal TP2** – Power input terminal for the converter. Adjacent to this terminal is the GND reference ground. Use this terminal to attach the EVM to a cable harness.
- **V_{OUT} — Terminal TP4**– Regulated output voltage for the converter. Adjacent to this terminal is the GND reference ground.
- **GND — Terminal TP3, TP5** – Ground reference for the converter. Use these terminals to attach the EVM to a cable harness.
- **Enable Setting — Jumper JP1** – Used to configure the enable circuit. Leave the pins open or short Pin2 with pin3 enables the circuit, short Pin2 to Pin1 disables the circuit. See Table 2-1 for details.

Table 2-1. EN Connections

EN Connection	Configuration
Leave all pins of JP1 open	Enable, EN connect to V_{IN} through a pullup resistor
Short Pin2 with pin3, leave Pin1 open	Enable, Programmable system UVLO by EN divider
Short Pin2 with pin1	Disable, EN connect to GND directly

- **Test point** — TP6, TP7, TP8, TP9, TP10, TP11 are test points. See Table 2-2 for details.

Table 2-2. Test Point connections

Reference Designator	Function
TP6(VIN_SNS)	Test point for V_{IN}
TP7(EN)	Test point for EN
TP8(INJ)	Test point for loop response measurement
T9(VOUT_SNS)	Test point for V_{OUT}
T10, TP11(GND_SNS)	Test point for GND

2.1.2 Adjusting the Output Voltage

To change the output voltage of the EVMs, change the value of resistor R_4 (R_{FB_TOP}) and resistor R_5 (R_{FB_BOT}). The value of R_4 and R_5 for a specific output voltage can be calculated using Equation 1.

$$V_{OUT} = 0.8 \times \left(1 + \frac{R4}{R5}\right) \quad (1)$$

2.2 Test Results

2.2.1 Output Voltage Ripple

The following images show the LMR51635EVM output voltage ripple waveforms. The output currents are as indicated.

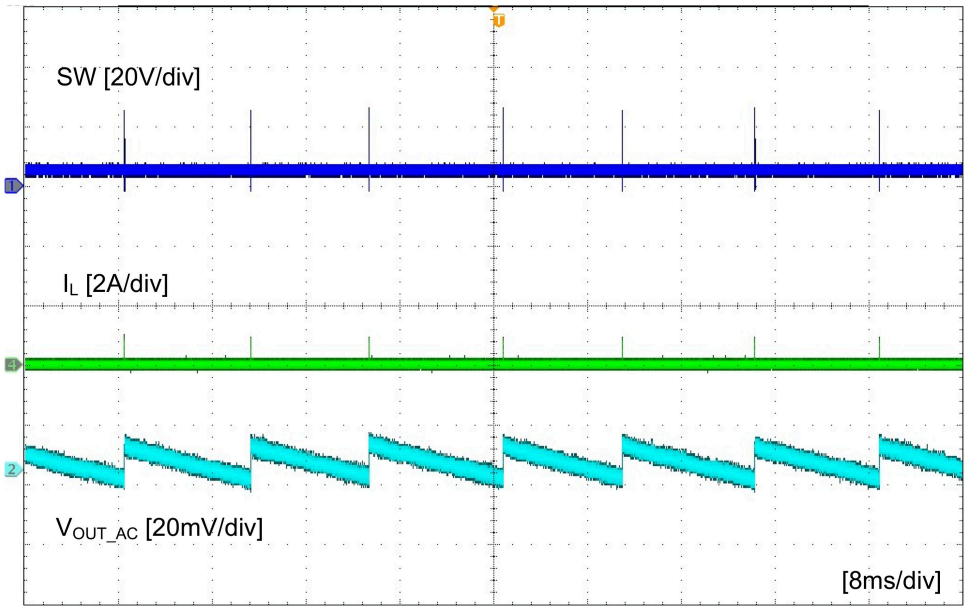


Figure 2-1. LMR51635EVM Output Voltage Ripple, V_{IN} = 24V, I_{OUT} = 0A

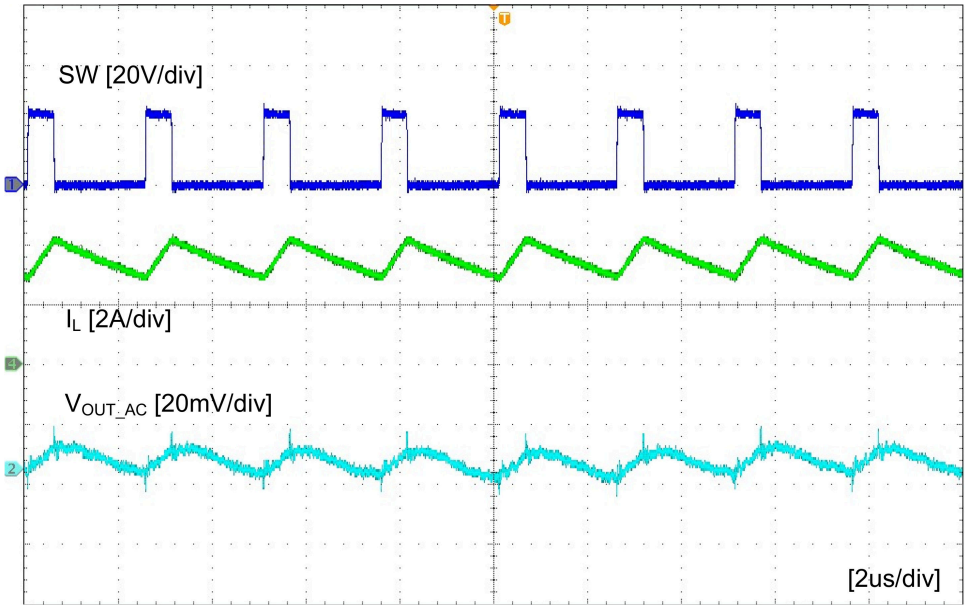


Figure 2-2. LMR51635EVM Output Voltage Ripple, V_{IN} = 24V, I_{OUT} = 3.5A

2.2.2 Start-Up Relative to V_{IN}

The following figure shows the LMR51635EVM start-up waveform relative to V_{IN}.

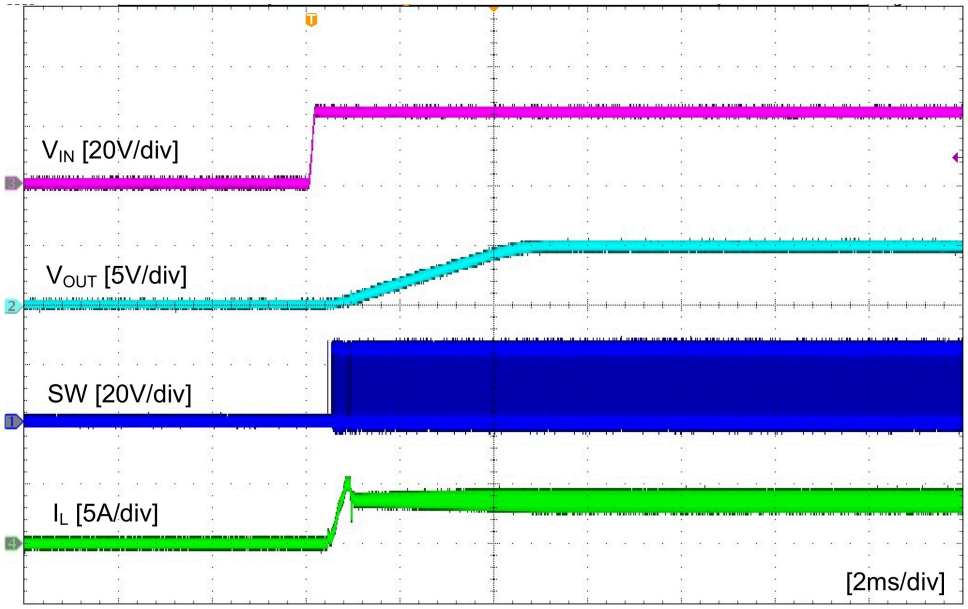


Figure 2-3. LMR51635EVM Start-Up Relative to V_{IN}, I_{OUT} = 3.5A

2.2.3 Start-Up Relative to EN

The following figure shows the LMR51635EVM start-up waveform relative to V_{IN}.

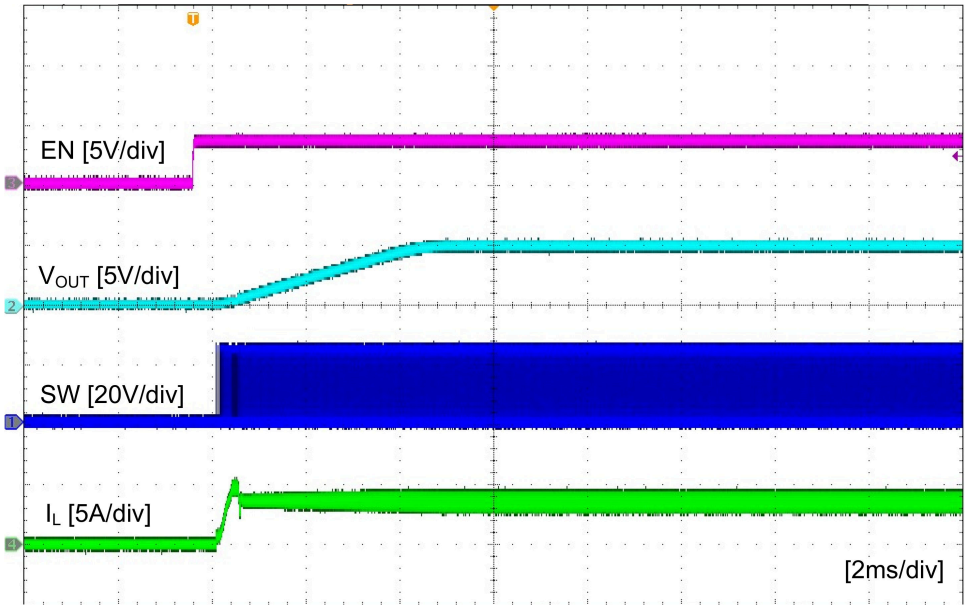


Figure 2-4. LMR51635EVM Start-Up Relative to EN, I_{OUT} = 3.5A

3 Hardware Design Files

3.1 Schematic

Figure 3-1 is the schematic for the LMR51635EVM.

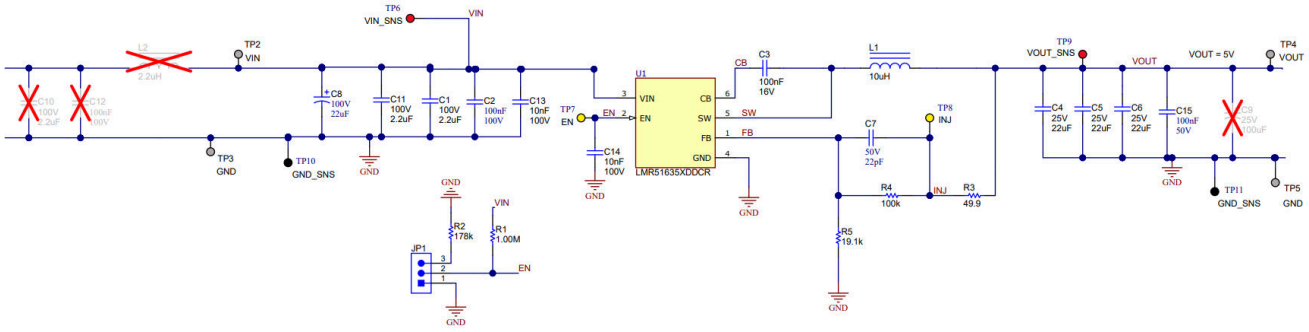


Figure 3-1. LMR51635EVM Schematic Diagram

3.2 PCB Layouts

This section provides a description of the LMR51635EVM, board layout, and layer illustrations.

The board images are shown in Figure 3-2 and Figure 3-3. The board layouts are shown in Figure 3-4 to Figure 3-7. The PCB consists of a 4-layer design. The board size is 55mm × 57mm. 2oz copper planes are applied on top and bottom layers, 1oz copper planes are applied on middle layers.

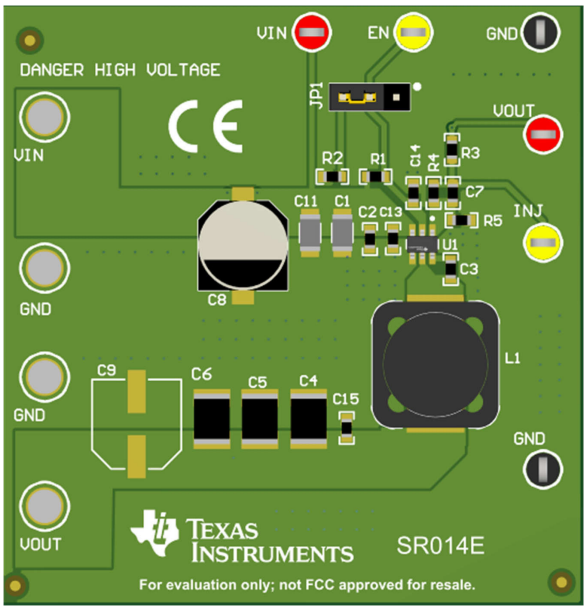


Figure 3-2. LMR51635EVM Front Photo

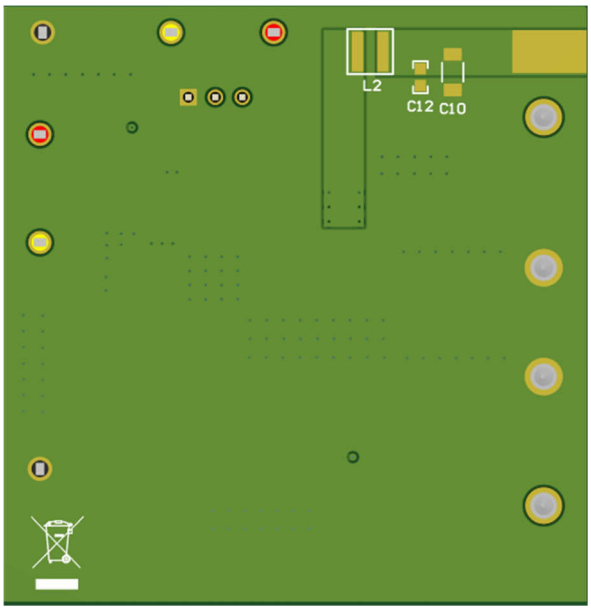


Figure 3-3. LMR51635EVM Back Photo

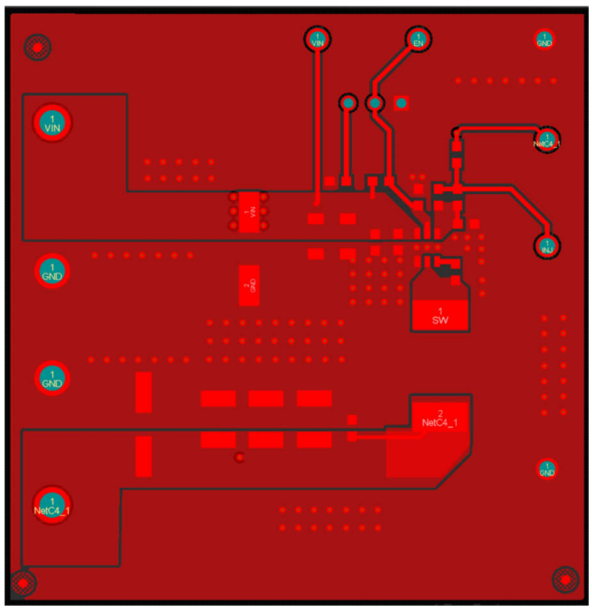


Figure 3-4. Top Layer

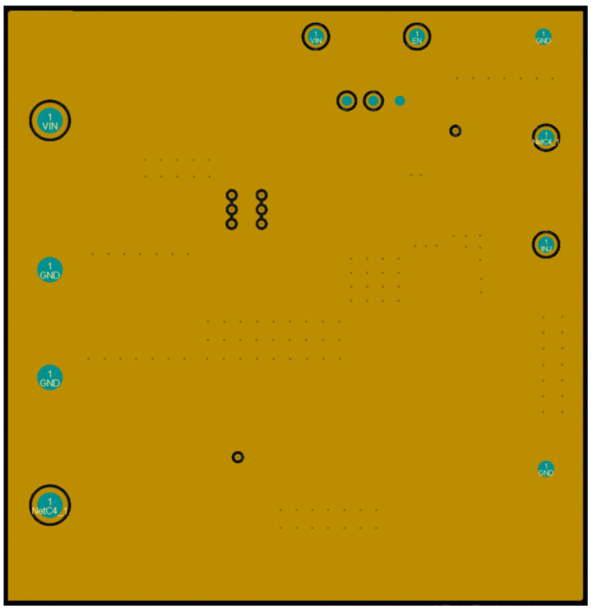


Figure 3-5. Middle Layer 1

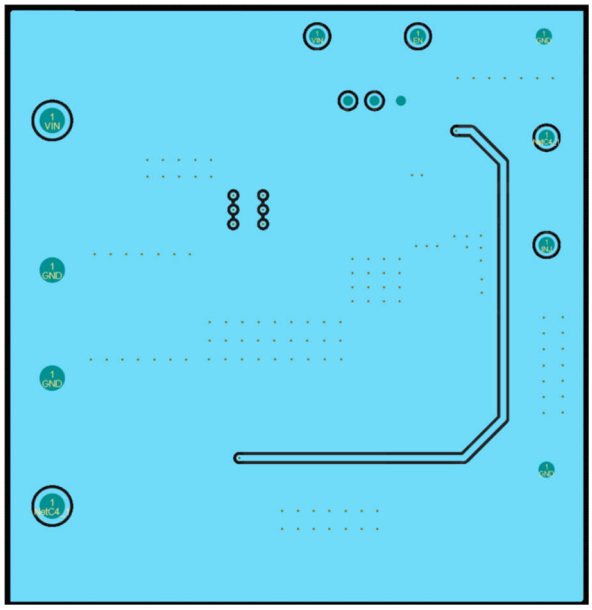


Figure 3-6. Middle Layer 2

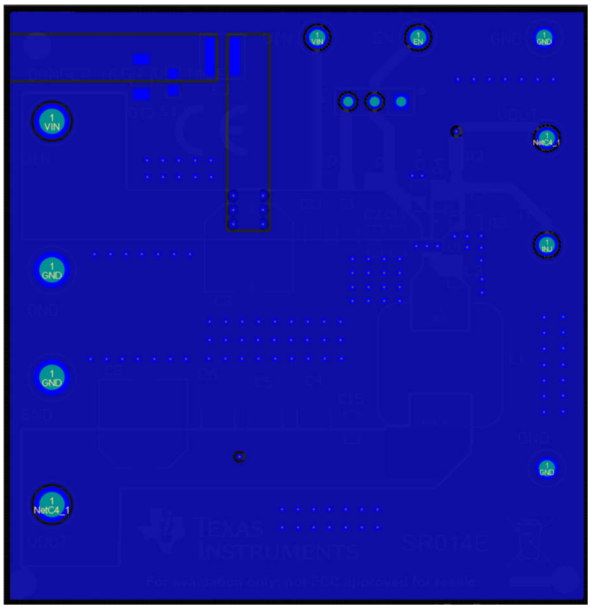


Figure 3-7. Bottom Layer

3.3 Bill of Materials

Table 3-1. Bill of Materials

Designator	QTY	Description	Part Number	Manufacturer
PCB	1	Printed circuit board, 2165 mil x 2244 mil	SR014	Any
C1, C11	2	CAP, CERM, 2.2uF, 100V, +/- 10%, X7S, 1206	C3216X7S2A225K160AB	TDK
C2	1	CAP, CERM, 0.1uF, 100V, +/- 10%, X7R, 0603	GRM188R72A104KA35J	MuRata
C3	1	CAP, CERM, 0.1µF, 16V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603YC104K4T4A	AVX
C4, C5, C6	3	CAP, CERM, 22uF, 25V, +/- 20%, X7R, AEC-Q200 Grade 1,	CGA8P1X7R1E226M250KC	TDK
C7	1	CAP, CERM, 22pF, 50V, +/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0603	CGA3E2C0G1H220J080AA	TDK
C8	1	CAP, AL, 22uF, 100V, +/- 20%, 1.3 ohm, AEC-Q200 Grade 2, SMD	EEE-FK2A220P	Panasonic
C13, C14	2	CAP, CERM, 0.01uF, 100V, +/- 10%, X7R, 0603	GRM188R72A103KA01D	MuRata
C15	1	CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, 0603	C1608X7R1H104K080AA	TDK
JP1	1	Header, 100mil, 3x1, Tin, TH	PEC03SAAN	Sullins Connector Solutions
L1	1	Inductor, Shielded Drum Core, Ferrite, 10uH, 4.09A, 0.021 ohm, SMD	74477110	Wurth Elektronik
R1	1	RES, 1.00M, 1%, 0.1W, 0603	RC0603FR-071ML	Yageo
R2	1	RES, 178k, 1%, 0.1W, 0603	CRCW0603178KFKEA	Vishay-Dale
R3	1	RES, 49.9, 1%, 0.1W, 0603	RC0603FR-0749R9L	Yageo
R4	1	RES, 100k, 1%, 0.1W, 0603	RC0603FR-07100KL	Yageo
R5	1	RES, 19.1k, 1%, 0.1W, 0603	RC0603FR-0719K1L	Yageo
SH-JP1	1	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G	Samtec
TP2, TP3, TP4, TP5	4	Terminal, Turret, TH, Do1502-2	1502-2	Keystone
TP6, TP9	2	Test Point, Multipurpose, Red, TH	5010	Keystone
TP7, TP8	2	Test Point, Multipurpose, Yellow, TH	5014	Keystone
TP10, TP11	2	Test Point, Multipurpose, Black, TH	5011	Keystone
U1	1	55V, 3.5A SIMPLE SWITCHER Synchronous Buck Converter SOT-23-6	LMR51635XDDCR	Texas Instruments

4 Reference

Texas Instruments, *LMR51635 4.3V to 60V, 3.5A Synchronous Buck Converter* data sheet

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   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

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User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

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4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

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